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Green Synthesis of Silver Nanoparticles using Sustainable *Manihot Esculenta* Leaf Extract: Phytochemical Screening and Effect of Operational Parameters

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Abstract — ***This research investigated the green synthesis of silver nanoparticles by means of* Manihot esculenta *leaf extracts through a bottom-up approach in a single-pot system. Investigations were conducted on the phytochemical analysis and optimization of temperature, volume ratio, concentration, reaction time, and other operational parameters. The synthesized silver nanoparticles were characterized using UV-Vis spectroscopy and FTIR analysis. Phytochemical screening of Manihot esculenta plant leaf extract showcased abundance of Saponins, flavonoids and trace number of triterpenes, tannins, alkaloids, and steroids. FTIR analysis confirmed the presence of biomolecules functioning as reducing, stabilizing, and capping agents. This study highlighted the importance of various operational parameters in the synthesis of silver nanoparticles (AgNPs). The optimal experimental conditions identified—90-minute reaction time at room temperature, 0.01 M concentration, and a volume ratio of 2:8 (plant extract to Ag^{+} ion solution) produced clear and distinct surface plasmon resonance (SPR) peaks. UV-Vis was used to monitor the synthesis, and SPR was responsible for the maximum wavelength of 450 nm. The green synthesis approach provides a potentially scalable and sustainable means of producing silver nanoparticles using environmentally bening and sustainable material.***

Keywords- phytochemicals, Manihot esculenta, nanoparticles, operational parameters, Fourier Transform Infrared Analysis (FTIR), UV-Vis Spectroscopy

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I. INTRODUCTION

A sustainable approach to the development of nanomaterial is offered by the green synthetic approach which provides a sustainable alternative to replacing toxic chemical route of nanoparticles synthesis. Advantageously, the green synthetic route can reduce the environmental impact of nanoparticles synthesis. It is posed to be environmentally friendly, reduce the use of hazardous chemicals, reduce consumption of energy, cost effective, encourage sustainability and it complies with environmental and safety regulations [1]. Environmental impact of nanoparticles can be improved and this biosynthetic route might lead to the development of unique properties and innovative applications [2], [3], [4]

The adaptable physicochemical characteristics of nanomaterials have drawn a lot of interest in nanotechnology as they enable a broad spectrum of applications across various industries, such as food, pharmaceuticals, and healthcare, water treatment; ingredients for cosmetics; antimicrobial textiles; and many more [10]. Since its introduction, nanotechnology has been hailed as the greatest scientific advance since it revolutionized modern medicine and significantly improved human health worldwide. By overcoming their drawbacks, therapeutic strategies based on nanotechnology can help eliminate the burden of antimicrobial resistance (AMR) and enhance the effectiveness of currently available treatments for bacterial infections linked to AMR [11]. MENPs have demonstrated a significant beneficial effect on wound healing when incorporated into wound dressings, as well as the prevention and treatment of infections. According to published research, using antimicrobial wound dressings can be seen as an additional strategy to lessen bacterial colonization and infection during the healing process. Because of their antimicrobial activity, NPs have shown promise not only for wound healing but also for tissue engineering, bone cement, urinary catheters, dental implants, food packaging, and wastewater treatment [12].Furthermore, AgNPs have demonstrated exciting potential for use as a potent antibacterial agent because of their unique physicochemical characteristics and broad-spectrum antibacterial activity, which make them perfect for treating infections brought on by AMR bacteria [13]. To be suitable for biomedical applications, nanomaterials must exhibit biocompatibility, be thoroughly characterized, and remain stable during in vivo testing [14]. The size and shape of NPs, among other physicochemical characteristics, dictate their biological efficiency. It is possible to easily modify the NPs' biochemical characteristics, such as their ability to interact with biological targets, their hydrophobicity, and their deeper tissue penetration, by changing their material, size, morphology, and electrical charge [14]. AgNPs made from various biological sources have been shown to have antimicrobial properties in a number of in vitro and in vivo investigations. Here are a few instances of green synthetic AgNPs and their useful uses: AgNPs produced using the aqueous leaf extract of *M. esculenta* exhibited antibacterial activity against *Pseudomonas aeruginosa*, *Bacillus cereus*, *Escherichia coli*, and *Staphylococcus aureus* [15].Green synthesized nanoparticle has greatly gained the attention of several researchers. Among the list of medicinal plants that have been used for silver nanoparticles synthesis are *Tithonia diversifolia* [11] *Eugenia roxburghii DC* [12]; *Curcuma longa [13]*; *Hibiscus rosasinensis [14]*; Pleurotus SP [15] and *Acalypha wilkesiana [16]*. Among the commonly used tropical plants for silver nanoparticle synthesis, *Manihot esculenta* leaves remain relatively unexplored. *Manihot esculenta*, a member of the Euphorbiaceae family, is extensively cultivated as a major agro-industrial crop worldwide. It is also referred to by other names, including Brazilian arrowroot, cassava, manioc, yuca, tapioca, mandioca, shushu, muk shue, cassave, manioc, tapioca, imanoka, maniba, kasaba, katela boodin, and sweet potato tree [16]. *Manihot esculenta* is cultivated by millions of people across Africa, Asia, and Latin America as a primary staple food Thailand ranks as the leading exporter of cassava starch, whereas Nigeria holds the position of the world's largest cassava producer.

This woody, perennial shrub has large, brown roots that have flesh that is either chalk-white or yellow inside, compound leaves, and tiny green flowers [17]. Over 105 countries cultivate cassava, with Nigeria, Thailand, the Democratic Republic of Congo, Indonesia, and Brazil being the top producers. More than 78.5 million tons of cassava produced worldwide in 1961, came from Africa. The amount of cassava produced worldwide surged to 322 million tons in 2017, with 26 million hectares of land being used for cultivation [18]. The nutritional, mineral, and phytochemical contents of cassava leaves, which include carbohydrates, dietary fibers, vitamins, phenolics, anthocyanins, and flavonoids, as well as essential amino acids (phenylalanine and methionine), can be responsible for their pharmacological potency and health benefits.

Numerous phytochemical analyses of cassava have demonstrated that the presence of multiple metabolites is responsible for the plant's biomedical activities. The leaves of M. esculenta, which are frequently thrown away during harvest, contain vitamin A, vitamin B1, calcium, calories, phosphorus, protein, fat, carbohydrate, and iron. M. esculenta contains flavonoids, tannins, alkaloids, ascorbic acid, and saponins, all of which have demonstrated antimicrobial, antioxidant, and anti-inflammatory properties [19]. Despite the numerous applications of *Manihot esculenta*, it was still listed as under-utilized plant because only few fractions of the world population have the knowledge of its wide application. Based on its underutilized nature, its unique properties and to the best of our knowledge, no reports have been published on the green synthesis of silver nanoparticles using *Manihot esculenta*, hence the prompting for this study. The scope of this study covers green synthesis, physicochemical properties and operational parameters determination of biosynthesized silver nanoparticles using the aqueous extract of *Manihot esculenta* leaves.

II. MATERIALS AND METHODS

A. Plant collection and Preparation of Extract

Fresh leaves of *Manihot esculenta* (Figure 1) were collected from Landmark University, Omu Aran. The leaves were plucked, washed and then pounded. Ten grams of the leaves were mixed with 10 grams of boiled water, allowed to stand for ten minutes, and then filtered using Whatman No. 1 filter paper. Figure 1 displays a picture of the cassava leaves that were used in this investigation.

Fig. 1: Image of Manihot esculenta (cassava) leaves

B. Phytochemical Screening

The phytochemical screening was carried out on the extract for the identification of constituents, according to standards. The constituents identified were alkaloids, tannins, phenols, triterpenes, flavanoids, saponins and steroids.

C. Synthesis of Manihot esculenta silver nanoparticles

Leaves from *Manihot esculenta* were gathered near Landmark University, gently cleaned to get rid of farm soil, and allowed to air dry to preserve essential volatile compounds. After the dried leaves were ground up, ten grams of finely ground *Manihot esculenta* were added to 500 mL of deionized water at 100 °C, and the mixture was left to stand for ten minutes. The extract was filtered using 185 mm Whatman filter paper, while procedures were replicated for the plant under study. A standard protocol involved measuring and adding 20 milliliters of leaf extract to a clean 250 milliliter beaker, which was then mixed with 80 milliliters of $1x10^3$ $AgNO_3$ at room temperature. On the mechanical shaker, the resultant solution was agitated under ideal operating circumstances [25].Centrifugation was used to separate the *Manihot Esculenta* silver nanoparticles (ME-AgNPs) at the ideal contact time of 4000 rpm. Phytochemical screening of the leaf extracts revealed the presence of phenols, saponins, triterpenes, flavonoids, alkaloids, and steroids.
This screening was done in using materials and methods provided in the Landmark university Laboratory

D. Experimental Optimization of Process Parameters for Silver Nanoparticle (AgNP) Synthesis

Studies were carried out to examine the impact of four operational parameters on the formation of ME AgNPs: Concentration, Contact time, Volume ratio and Temperature.
Silver nitrate served as the source of silver ions and the main precursor that provides silver ions (Ag^+). The batch operational parameter was examined using the methodology outlined in previous research, following a batch process approach.[9]. The concentrations of AgNO3 reacting with Manihot esculenta leaf extract were 0.001 M, 0.002 M, 0.004 M, 0.006 M, 0.008 M, and 0.01 M. The reaction mixture was monitored over a period of 0 to 90 minutes to identify the optimal contact time for silver nanoparticle synthesis. Additionally, the effect of volume was studied by varying the AgNO3 concentration, using ratios of 2:8 and 8:2.

III. RESULTS AND DISCUSSION

A. Phytochemical screening results

Phytochemical screening identified the presence of several biomolecules involved in the reduction of silver ions (Ag^+ to Ag^0), this confirmed the suitability of the plant extracts for this study, this also confirmed its scalability and production in an economically feasible manner. From the outcome of the phytochemical screening, it was observed that *Manihot esculenta* contained polyols and biomolecules which is a good constituent for bio-reduction and also synthesis of silver nanoparticles.

Table 1 shows the results observed during phytochemical analysis for *Manihot esculenta*.It revealed the presence of steroids, flavonoids, triterpenes, saponins, and alkaloids, with flavonoids and saponins showing the highest intensity in Manihot esculenta. Literature supports the outcome that was achieved [22].

Table 1*: Phytochemical screening results for Manihot esculenta leaf extract*

Phytochemical	inference
Triterpenes	+
Saponins (Froth test)	+ +
Tannins and phenolic compounds ($FeCl_3$ test)	+
Flavonoids (test with NaOH)	+ +
Alkaloids (Mayers test)	+
Steroids (Salkowski test)	+

indicates present, while ++ indicates abundance

B. Visual monitoring of the synthesis of ME-AgNPs.

AgNPs were synthesized through a green process using an aqueous plant extract as the reducing agent and AgNO3 as the precursor for silver (Ag+) ions. A discernible shift in the leaf extract-$AgNO_3$ mixture solution's color indicated the presence of the bio-reduction reaction. Prior to being combined with the clear $AgNO_3$ solution, the CLE had a golden-brown color, which was then slightly darker to produce the ME-$AgNO_3$ mixture. A distinct color change from golden-brown to dark brown was observed over time, indicating the formation of AgNPs from the Ag+ ion precursor.

The surface plasmon resonance (SPR) and Ag+ bio-reduction caused by the phytochemicals in the leaf extracts are responsible for the color shift [24].

C. UV-Vis Spectroscopy of Manihot esculenta silver nanoparticles

Investigations were carried out to examine the impact of four operational parameters on the formation of ME-AgNPs: concentration, contact time, volume ratio, and temperature.Using the methodology outlined in previous research, the batch operational parameter was explored through a batch approach. [28]. The concentrations of reacting AgNO3 with Manihot esculenta leaf extract were 0.001 M, 0.002 M, 0.004 M, 0.006 M, 0.008 M, and 0.01 M. The reaction mixture was monitored over a period of 0 to 90 minutes to identify the optimal contact time for the synthesis of silver nanoparticles.
Additionally, the effect of volume was assessed by varying the AgNO3 volume ratio, using ratios of 2:8 and 8:2. Finally, the temperature effect was examined at 45°C and 55°C.

D. Effect of Concentration

This operational parameter was observed under ideal circumstances and at different silver ion solution concentrations. The following concentrations were used in the investigation: 0.001, 0.002, 0.004, 0.006, 0.008 and 0.01 M. This operational parameter was tested at various concentrations of the silver ion solution. The concentrations used under study includes: 0.001, 0.002, 0.004, 0.006, 0.008 and 0.01 M. For all the various concentrations, the intensity rises as the Ag+ concentration rises with the SPR peak. The effect of concentration was determined by adjusting the different Ag+ concentrations: 0.001 M, 0.002 M, 0.004 M, 0.006 M, 0.008 M, and 0.01 M. The increase in

particle size results in an increase in spectrum intensity at higher concentrations [26]. As seen in Figure 2, the optimal concentration of 0.01 M exhibited the strongest surface plasmon resonance (SPR), which was detected at 450 nm. The FTIR analysis results were used to identify the functional groups in the extracts that serve as reducing and capping agents. The signals observed and their corresponding bands confirmed the presence of these phyto molecules. This research was corroborated by [28].

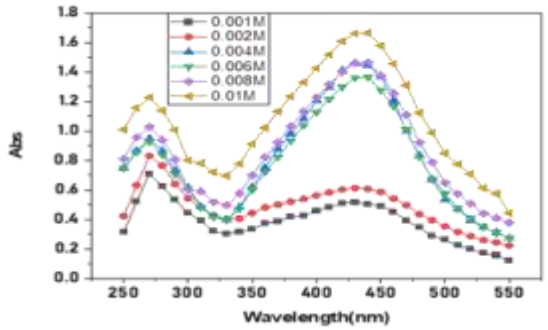


Figure.2: UV-Vis Spectroscopic analysis of silver nanoparticles from Manihot esculenta.

E. Effect of Contact Time

Significant roles are played by the temperature and reaction time operational parameters in the synthesis of ME-AgNPs. Figure 3 displays the UV-vis absorption spectra for the different reactions, illustrating how contact time influences the formation of ME-AgNPs. By continuously observing the reaction between the plant extract and $AgNO_3$ for 30, 45, 60, and 90 minutes, the effect of reaction time was studied at room temperature. The impact of contact time on the formation of ME-AgNPs was investigated by monitoring the reaction between the plant extract and AgNO3 at intervals of 30, 45, 60, and 90 minutes.A color change from green to brown was observed within ten minutes of the reaction between the ME extract and AgNO3 solution. As time went on, the color became more vivid. UV-Vis measurements were recorded at different time intervals. As the time interval increased, a color shift from green to red and then steadily to brown was seen [17]. Since the peak's intensity depends on the contact time, it rises as the time increases. The SPR (Surface Plasmon Resonance) band broadened in the first 30 minutes due to the gradual conversion of silver ions (Ag^+) into zerovalent silver (Ag^0) nanoparticles. The optimal surface plasmon resonance and the highest absorption peak were observed at 90 minutes. and this was the ideal time for all subsequent investigations to be conducted [18].

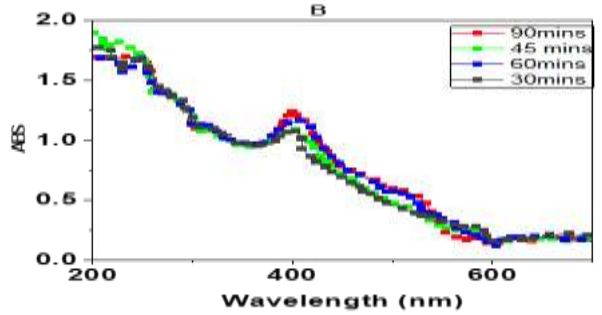


Figure.3: UV-vis absorption spectra for the different reactions, highlighting the impact of contact time on the formation of ME-AgNPs.

F. Impact of Volume Ratio

The effect of volume ratio can be seen in figure 4. This was investigated by changing the volume ratio of the leaf extract to 0.001M Ag+ solution to 2:8 and 8:2.

As the volume of Ag+ solution increased, the absorption peak became sharper, and the intensity of the absorption band at 428 nm significantly enhanced.

The most prominent SPR peaks in the UV-Vis spectra were observed at the 2:8 ratio. As a result, the research was conducted using these volumes.

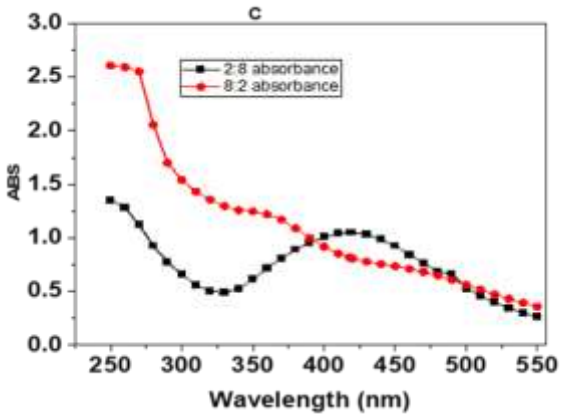


Figure.4: UV-vis absorption spectra showing the effect of volume ratio on the formation of ME-AgNPs

G. Effect of Temperature

An additional investigation into the impact of temperature on AgNP synthesis was conducted at 45ºC and 55º. According to reports, a rise in temperature causes the SPR band's intensity to increase due to a bathochromic shift, which decreases the mean diameter of AgNPs. However, this may not necessarily indicate the optimal temperature for achieving a strong SPR band.Since the biomolecules from the ME extract effectively reduced and stabilized AgNPs at room temperature, good representation was obtained in this study. At room temperature, stable ME-AgNPs were formed, supporting the emphasis on the green synthetic route.

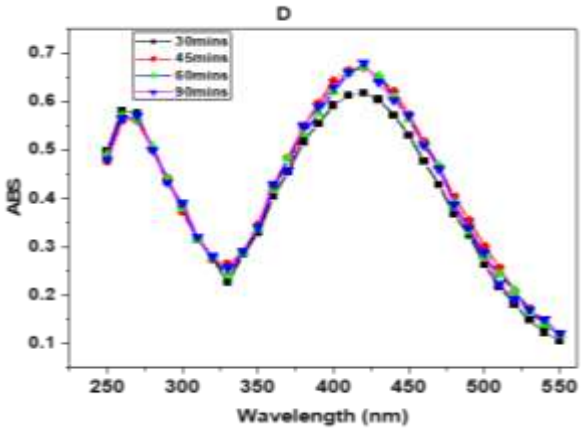


Figure 5: *Effect of Temperature at 45 ˚C*

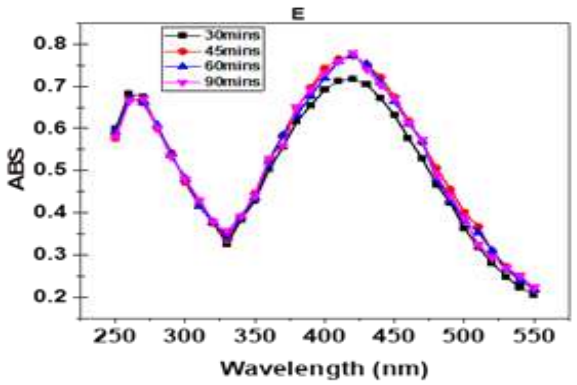


Figure 6: *Impact of Temperature at 55 ˚C*
UV-vis absorption spectra illustrating the effect of temperature—specifically 45 °C and 55 °C—on the formation of ME-AgNPs.

H. *Fourier Transform Infrared Spectroscopy (FTIR) Analysis*.
Fourier Transform Infrared Spectroscopy (FTIR) was performed on both the *Manihot esculenta* leaf extracts and the synthesized ME-AgNPs.This is illustrated in figures 7 and 8. The presence of some functional groups led to the formation of Ag nanoparticles. The figures display a shift in band, which indicates active participation of bioactive groups in the bio-reduction of Ag^{+} to Ag^{0}. A signal at 3265.1 cm^{-1} corresponds to the –OH stretching vibration, and the –C=C– stretch is observed at 1654 cm^{-1}. The signal at 1088cm^{-1} is also represents the C-O band and 2918.5cm^{-1} indicates the presence of a saturated aliphatic hydrocarbon which represents the C-H band. As seen in Figure 7 and Figure 8 for *Manihot esculenta* leaf extracts. Detected phyto-compounds include phenols, terpenoids, saponins, and flavonoids" which is indicated by the functional groups, which implies that the biomolecules play roles in stabilization, reduction and capping agents, in the two parts, the researcher's report in the literature [11] corroborated this conclusion. The figures reveal the observed shift in the bands indicating that biologically active compounds played a key role in the bio-reduction of Ag^{+} to Ag^{0}. The –OH group is identified by the signal at 3265.1 cm^{-1}, while the –C=C– group is observed at 1654 cm^{-1}, the signal at 1088cm^{-1} also represents the C-O band and 2918.5cm^{-1} indicates the presence of a saturated aliphatic hydrocarbon which represents the C-H band. As seen in Figure 7 and Figure 8 for *Manihot esculenta leaf* extracts.

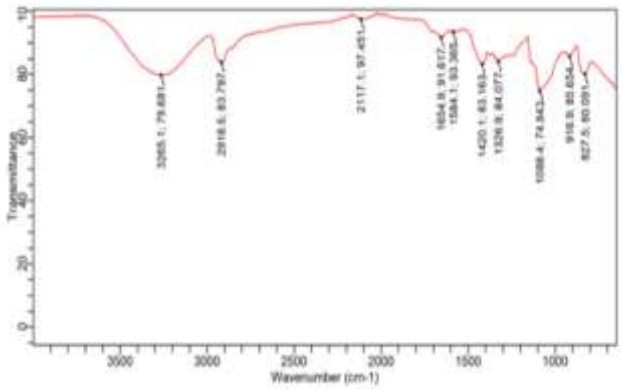
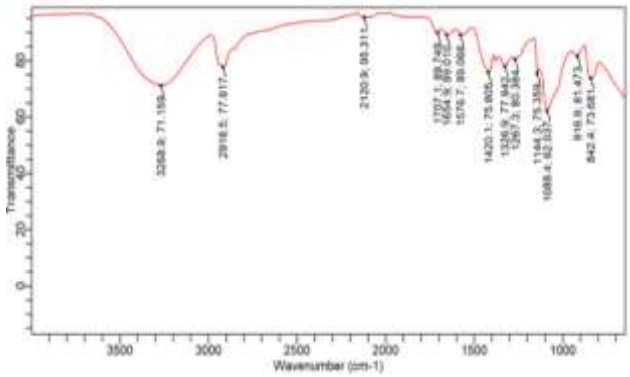


Figure7: FTIR spectrum of Manihot Esculenta leaf extract



Figutre8: FTIR spectrum of the synthesized ME-AgNPs

The results from the UV-Vis analysis showed how various physicochemical parameters were optimized to obtain maximum yield of the synthesized Nanoparticles.

IV. CONCLUSION

Phytochemical screening identified flavonoids, triterpenes, and saponins as the dominant biomolecules, which may act as reducing, stabilizing, and capping agents in the conversion of Ag^{+} to Ag^{0}. Silver nanoparticles (AgNPs) from *Manihot Esculenta* (Cassava) leaf extracts were synthesized. This work demonstrated the effective synthesis of silver nanoparticles (AgNPs) with environmentally friendly extracts from cassava leaves. The optimal yield of ME-AgNP was favorably influenced by the following parameters: an ambient temperature was maintained to preserve biomolecule stability, with a reaction time of 90 minutes and an optimal Ag^{+} solution concentration of 0.01 M and volume ratio of 2:8, as the synthesis of ME-AgNPs depended on various experimental operational parameters. A surface plasmon resonance peak was detected at 450 nm using UV–Vis spectroscopy, while FTIR analysis confirmed the presence of functional groups including hydroxyl, carbonyl, alkenes, and saturated aliphatic groups, showing their signals and corresponding bands. Potential applications can be found in the medical as well as Industrial sector. This green synthesis approach provides a potentially scalable and sustainable means of producing AgNPs.

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REFERENCES

[1] F. U. Haider, U. Zulfiqar, N. Ain, Saddam Hussain, M. F. Maqsood, Mukkaram Ejaz, Jean Wan Hong Yong, Yuelin Li, Harnessing plant extracts for eco-friendly synthesis of iron nanoparticle (Fe-NPs): Characterization and their potential applications for ameliorating environmental pollutants, Ecotoxicology and Environmental Safety,Volume 281,2024, 116620, https://doi.org/10.1016/j.ecoenv.2024.116620.

[2] Dada, A.O., Adekola, F.A., Dada, F.E., Adelani-Akande, A.T., Bello, M.O. Okonkwo, C.R., Inyinbor, A. A., Oluyori, A.P., Olayanju, A.,

Ajanaku, K.O., Adetunji, C.O. (2019). Silver nanoparticle synthesis by Acalypha wilkesiana extract: phytochemical screening, characterization, influence of operational parameters, and preliminary antibacterial testing, Heliyon, Volume 5, Issue 10,2019,e02517, https://doi.org/10.1016/j.heliyon.2019.e02517.

[3] Shuaixuan Ying, Zhenru Guan, Polycarp C. Ofoegbu, Preston Clubb, Cyren Rico, Feng He, Jie Hong,Green synthesis of nanoparticles: Current developments and limitations,Environmental Technology & Innovation,Volume 26,2022, 102336, https://doi.org/10.1016/j.eti.2022.102336

[4] Abady, M.M., Mohammed, D.M., Soliman, T.N., Shalaby, R.A., and Sakr, F.A. (2025). Sustainable synthesis of nanomaterials using different renewable sources. *Bulletin of the National Research Centre (2025) 49:24* https://doi.org/10.1186/s42269-025-01316-4

[5] S. &. Z. J. Tang, "Antibacterial activity of silver nanoparticles: structural effects.," *Advanced healthcare materials.*, Vols. 7(13), 1701503, 2018

[6] S. &. B. L. Rajeshkumar, ". Mechanism of plant-mediated synthesis of silver nanoparticles–a review on biomolecules involved, characterisation and antibacterial activity.," *Chemico-biological interactions*, vol. 273, pp. 219-227., 2017.

[7] N. A. Rosli, Y. H. Teow and E. & Mahmoudi, "Current approaches for the exploration of antimicrobial activities of nanoparticles.," *Science and technology of advanced materials*, vol. 22, no. 1, pp. 885-907., 2021.

[8] Z.-m. Xiu, Q.-b. Zhang, H. L. Puppala, V. L. Colvin and P. J. & Alvarez, "Negligible particle-specific antibacterial activity of silver nanoparticles.," *Nano letters*, vol. 12, no. 8, pp. 4271-4275. , 2012.

[9] A.-W. Ajlouni, E. H. Hamdan, R. A. E. Alshalawi, M. R. Shaik, M. Khan, M. Kuniyil, A. Alwarthan, M. A. Ansari and M. &. A. H. Z. Khan, "Green synthesis of silver nanoparticles using aerial part extract of the Anthemis pseudocotula boiss. plant and their biological activity.," *Molecules*, vol. 28, no. 1, p. 246.

[10] S. C. Wattimena, D. A. Ayuningrum, L. Y. Latuasan, E. Samson and P. J. & Patty, "Properties of Bio-Silver Nanoparticles Mediated by Tuber and Leaf Extracts of Manihot esculenta. Biosaintifika," *Journal of Biology & Biology Education,*, vol. 14, no. 2, 2022.

[11] Dada AO, Inyinbor AA, Idu EI, Bello OM, Oluyori AP, Adelani-Akande TA, Okunola AA, Dada O. 2018. Effect of operational parameters, characterization and antibacterial studies of green synthesis of silver nanoparticles using *Tithonia diversifolia*. PeerJ 6:e5865 https://doi.org/10.7717/peerj.5865

[12] Giri AK, Jena B, Biswal B, Pradhan AK, Arakha M, Acharya S, Acharya L. Green synthesis and characterization of silver nanoparticles using Eugenia roxburghii DC. extract and activity against biofilm-producing bacteria. Sci Rep. 2022 May 19;12(1):8383. doi: 10.1038/s41598-022-12484-y. PMID: 35589849; PMCID: PMC9120126.

[13] Fatimah, I.; Hidayat, H.; Purwiandono, G.; Khoirunisa, K.; Zahra, H.A.; Audita, R.; Sagadevan, S. Green Synthesis of Antibacterial Nanocomposite of Silver Nanoparticle-Doped Hydroxyapatite Utilizing *Curcuma longa* Leaf Extract and Land Snail (*Achatina fulica*) Shell Waste. *J. Funct. Biomater.* **2022**, *13*, 84. https://doi.org/10.3390/jfb13020084

[14] S. Periasamy, U. Jegadeesan, K. Sundaramoorthi, T. Rajeswari, V. N. B. Tokala, S. Bhattacharya, S. Muthusamy, M. Sankoh, and M. K. Nellore. 8123854 Comparative Analysis of Synthesis and Characterization of Silver Nanoparticles Extracted Using Leaf, Flower, and Bark of *Hibiscus rosasinensis* and Examine Its Antimicrobicidal Activity. (2022). Journal of Nanomaterials, Volume 2022, Article ID 8123854, 10 pages, https://doi.org/10.1155/2022/

[15] O. O. Osemwegie *et al*., "Biosynthesis, Characterization and Optimization of Silver Nanoparticles Using Exopolysaccharide from Pleurotus SP," *2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG)*, Omu-Aran, Nigeria, 2024, pp. 1-8, doi: 10.1109/SEB4SDG60871.2024.10629659.

[16] da Silva Santos, B. R., Silva, E. F. R., Minho, L. A. C., Brandao, G. C., dos Santos, A. M. P., dos Santos, W. P. C., Silva, M. V. L., & dos Santos, W. N. L. (2020)., "Evaluation of the nutritional composition in effect of processing cassava leaves (Manihot esculenta) using multivariate analysis techniques.," *Microchemical Journal*, , vol. 152, no. 104271, 2020.

[17] S. S. Jamil and A. Bujang, "Nutrient and antinutrient composition of different variety of cassava (Manihot esculenta Crantz) leaves.," *Jurnal Teknologi*, vol. 78, no. 6, pp. 59-63. , 2016.

[18] A. B. B. M. W. M. R. O. L. L. M. &. V. S. L. (. Amelework, "On-Farm Multi-Environment Evaluation of Selected Cassava (Manihot esculenta Crantz) cultivars in South Africa Plants," vol. 11, no. 23, p. 3339. , 2022.

[19] A. C. S. d. R. V. J. D. d. S. S. L. B. d. S. L. M. R. d. S. N. K. V. &. d. S. P. H. M. de Lima, "Processing of three different cooking methods of cassava: Effects on in vitro bioaccessibility of phenolic compounds and antioxidant activity.," *LWT-Food Science and Technology*, vol. 76, pp. 253-258. , 2017.

[20] S. R. N. S. P. Mohidin, S. Moshawih, A. Hermansyah, M. I. Asmuni, N. Shafqat and L. C. & Ming, "Cassava (Manihot esculenta Crantz): A systematic review for the pharmacological activities, traditional uses, nutritional values, and phytochemistry.," *Journal of Evidence-Based Integrative Medicine*, p. 28, 2023

[21] O. &. O. j. Oluwaniyi, " Comparative studies on the phytochemicals, nutrients and antinutrients content of cassava varieties.," *Journal of the Turkish Chemical Society Section A: Chemistry*, Vols. 4(3), 661-674., no. 4(3), 661-674., pp. 4(3), 661-674., 2017.

[22] N. Minatchy, C. Marie-Magdeleine, V. Calif, Y. Félicité, F. Periacarpin, C. Deloumeau and F. &. A. H. Pommier, "Minatchy, N;Marie-Magdeleine, C; Calif, V; Félicité, Y; Periacarpin, F., Deloumeau, C; Pommier, F & Archimède, H.," *Dichanthium hay combined with green cassava foliage or pelleted cassava foliage as fed for Black Belly rams.Tropical animal health and production*, vol. 52, no. 2, pp. 583-589. , 2020.

[23] R. Mustarichie and S. &. R. D. Sulistyaningsih, "Antibacterial activity test of extracts and fractions of cassava leaves (Manihot esculenta Crantz) against clinical isolate," *International journal of microbiology*, 2020.

[24] S. C. Wattimena, D. A. Ayuningrum, L. Y. Latuasan, E. Samson and P. J. & Patty, "Properties of Bio-Silver Nanoparticles Mediated by Tuber and Leaf Extracts of Manihot esculenta. Biosaintifika:," *Journal of Biology & Biology Education*, vol. 14, no. 2, 2022.